Sustainability and optimization of rangeland uses : issues of perspective and scale

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Key points : Numerous environmental factors that influence sustainable provision of rangeland commodities and ecosystem services are undergoing rapid , unprecedented change . Stakeholders making claims on rangeland products are increasingly diverse and contribute to policy decisions that shift management priorities . Many of the environmental processes and stakeholder demands transcend traditional rangeland delineation . Challenges to sustainability and optimization of rangeland uses emerge as temporal and spatial scales of management expand . Scientific insight regarding these emergent issues is a limiting factor to adaptive management attempts to reconcile social , economic , and ecological considerations in ways that are compatible with sustainability goals . Broadening the scope of scientific inquiry to more effectively integrate issues of perspective and scale can enhance the effectiveness of adaptive rangeland management .

Key words : sustainability , optimization , ecology , management , policy

Introduction

Rangelands—broadly defined as all uncultivated land with the potential to support grazing by domestic animals—cover about 70% of the world's land area (Holechek et al . 2004) . It is well recognized that the vast rangeland cover type provides multiple products and services to society (e .g . , livestock , wildlife , water , recreation , minerals , forage and other plant products , aesthetics/existence value) .

The magnitude of the challenges facing rangeland managers of today is unprecedented in the history of civilization . Many factors influencing rangelands are undergoing a pattern of rapid change , as depicted by the function illustrated in Figure 1 .

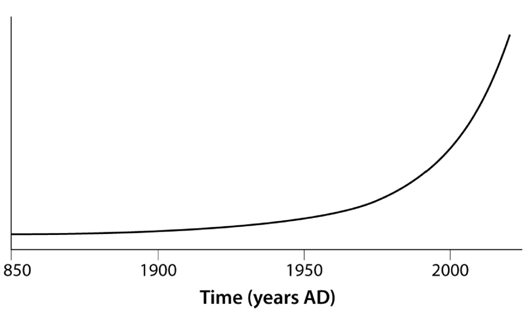

Figure 1 *Exponential function reflecting the rapidly changing environmental variables that influence rangelands .*

The y-axis on the figure is intentionally not labeled . Please pause and think for a moment about what different types of environmental variables could be plotted on the y-axis to match the function plotted on the graph .

Examples of environmental changes following the pattern of rapid increase illustrated in Figure 1 include :

- Global human population (US-CB 2004) . Throughout much of the world the primary factor propelling intensified use of natural resources is the increasing consumptive demand associated with the increase in the number of people . Some of the most rapid population growth rates in the world are in the African countries , where semi-arid rangelands dominate .
- Global food production (Goklany 1999) . Increasing global food production has allowed human populations to continue to rise . Most gains in food production are related to expanding the area used for irrigated agriculture , often on what had originally been rangelands .
- Water consumption (UN-FAO 2000) . Increasing irrigated agriculture is the primary element driving the increases in global water consumption and the corresponding reduction in base flow that historically maintained riparian habitats and dry-season pasture , often the most critical component influencing the overall production potential and patterns of use of rangeland landscapes .
- Soil degradation (Pimentel et al . 2004) . Increasing cultivation of lands is strongly tied to increases in global soil erosion , waterlogging , and salinization rates .
- Extinction rates (Pimm et al . 1995) . Increasing land conversion to agriculture and use of water for irrigation are the greatest sources of habitat loss which , in turn , reduces biodiversity and increases the risk of extinction .
- Atmospheric carbon dioxide (Keeling et al . 2005) . The dynamics of global climate change are complex , but there is growing consensus that rangeland-dominated high elevation and arctic biomes and water-limited grasslands and savannas

biomes are likely to experience the greatest changes to the structure and function of associated ecosystems (Walker et al. 1999).

- Combustion of fossil fuels (US-DOE 2007). Fossil fuel use has many impacts in addition to the increase in atmospheric carbon dioxide. The mines and drilling operations located on rangelands are a significant source of fossil fuel production. The scale of disturbance at these sites often poses great challenges to maintaining the integrity of the existing plant and animal communities. Reclamation is often a great challenge on rangelands which, due to climatic constraints, are often slow to recover. This is especially true when invasive species have colonized the disturbed areas and/or there has been substantial disruption of water and nutrient cycles.

Numerous other environmental factors are increasing at an exponential rate; for the sake of this discussion, the key point is that these trends illustrate that many of the challenges faced by rangeland managers today are increasingly driven by dynamics that transcend the temporal and spatial scales that are the current focus of most rangeland management decisions and most rangeland research efforts. This mismatch between the scale of relevant processes and the management objectives of local and regional interests is a growing challenge to rangeland stewardship. These challenges are further complicated by the fact that the intensity of rangeland use is increasing. Furthermore, the priorities for the products provided by rangeland to society are increasingly determined by distant stakeholders who do not make their living directly from traditional husbandry of livestock.

Philosophical foundations of rangeland management

The philosophical underpinnings of the rangeland management profession involve the simultaneous pursuit of two goals: 1) to strive for sustainable conservation and development of the rangeland resource and 2) to optimize the production of goods and services in combinations sought by society. To implement actions to achieve goals, the goals themselves must be clearly understood. Both of the goals of rangeland management are complex and value-laden. The concept of sustainability requires meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987). Stated another way, sustainability means preserving the principal and learning to live off of the interest. This definition implies a moral obligation to current and future generations for wise resource stewardship, thereby reflecting a strong element of ethics. The concept of optimization embodies the belief that it is desirable and possible for humans to shape their environment to serve their objectives. Optimization also assumes that the mix of goods and services sought by society may change over time as conditions change. Such changes in preferences are likely to be driven by the host of environmental factors that could be plotted on the y-axis of Figure 1.

Getting ahead of the curve" is a common phrase signifying the need for proactive leadership. It will be very difficult to cope with the implications of the various environmental issues represented by the exponential curve depicted in Figure 1. Even though crafting strategic research decisions and management configurations to be responsive to the needs of evolving rangeland uses and policies will no doubt be immensely challenging, it is our duty to try. When facing the great issues of his time, Abraham Lincoln said, You cannot escape the responsibility of tomorrow by avoiding it today." These words are appropriate for characterizing the substantial, unprecedented challenges faced by the rangeland management profession today.

Challenges to making the philosophical foundation operational

Is the character of the rangeland profession up to tackling what is ahead? Stressful situations do not build character as much as they provide a chance to let shine the character that is already ingrained. The role of values, and the responsibility of scientists, managers, and policy makers to making those values operative, raises many thorny issues that are highly relevant to professionals working with rangeland resources. Too often sustainability and optimization are used as rhetorical buzzwords, assumed to embody generally accepted standards of correctness (Callicott et al. 1999). In reality, individual values and experience influence perception, so there is a wide range of viewpoints about how the ecological, economic, and social components of the human environment should be melded to achieve sustainability and optimization.

Just as each of the legs on a three-legged stool must be present and be in balance with the others, so is there a need for ecological, economic, and social components to be truly integrated. Each component has something vital to offer to managers and policy makers. Ecology probes the structure and function of biophysical processes upon which all life depends. Economics addresses the costs and benefits of consumption, conservation, and development. Sociology considers community and cultural values and the social conventions and institutions used to influence behavior. Put another way, ecological and economic disciplines tend to focus on identifying options and tradeoffs. This information is processed through a social filter to develop the policy framework within which management must function (Goodland 1995).

A commonly stated objective of rangeland scientific inquiry is to provide information that will improve management and policy. There are many practical obstacles to achieving this objective. Most scientists are trained in highly specific disciplines. Most research is strongly influenced by short-term (2 to 5 year) planning and budget cycles. Most scientific journal review processes focus on precision. These factors combine to encourage scientists to conduct efficient experiments that study one or two variables while all others are held constant. To do this, small-plot field designs are usually used to enable replication and to control variability and cost. Given these issues, it is not surprising that integrated ecological, economic, and social research is rarely undertaken at the temporal and spatial scales at which management happens. Consequently, managers and policy makers are often exasperated because most scientific research is not conducted or presented in ways which are relevant to their needs, and yet, scientists feel they have special insight that entitles them to express their criticism of managerial or policy actions (Baskerville 1997). Furthermore, since scientists, managers, and policy makers are usually the products of highly discipline-specific graduate programs within universities, it is not surprising that rangeland development projects are often compartmentalized to focus on a particular sector and a single discipline. This is often done to foster the short-term efficiency of crafting a team who can work together without encountering the sometimes uncomfortable and always time consuming transaction costs associated with melding cross-disciplinary perspectives.

Failure to reconcile emergent issues at the interface between the ecological, economic, and social considerations has repeatedly resulted in management and policy actions that do not achieve the objectives of optimizing yield of rangeland products in a sustainable manner. The magnitude of this problem is further complicated by temporal or spatial scale mismatches between biophysical processes and socio-economic expectations (Lee 1993). When perception is not able to encompass the full range of process, there is a danger that expectation will be incorrect, thus the resource will be degraded. Expectation is an exceedingly difficult variable for management to deal with because various forms of the term are synonymous with anticipation (e.g., expected forage production on a site based on past experience), hope (e.g., hopeful inaction waiting for cattle prices to rise or a drought to end regardless of whether there is any information available to support or contradict the hoped for condition), and demand (e.g., expectation that historical livestock grazing use patterns should be maintained regardless of other societal changes that may alter prioritization of products within the context of multiple use policy). When many variables affecting rangelands have the functional relationship depicted in Figure 1, it is unclear how expectations regarding biophysical and socio-economic factors are likely to interact. The result is uncertain, difficult to predict, hard to change and likely to generate conflict.

To have any realistic prospect of meeting the challenges posed by the rapidly changing future, it is vital that research, management, and policy formulation be coordinated in temporal and spatial scales which make sense. In space and time, different issues emerge as scale changes. These emergent properties are endlessly difficult to study and manage. Rangeland scientific inquiry can make progress toward its joint objectives of sustainability and optimization by paying keen attention to issues of scale, as detailed below.

Temporal scale issues

Perception of normal

Management and policy expectation tends to be heavily influenced by experience in the recent past. This puts the resource in danger of being subject to a managerial and political ratchet effect. This phenomenon is initiated when a period of favorable resource conditions is accompanied by a gradual shift in expectation and an increase in capital investment designed to optimize management of the current level of resource production. When conditions return to a long-term normal or below normal, there is often intense pressure for the government to protect the people (and their investments) who have become dependent on the favorable conditions being maintained. The term ratchet effect was first coined to express difficulties in managing irregular fluctuations in marine fisheries (Caddy and Gulland 1983), but is also applicable to managing irregular fluctuations of rangeland products such as forage and water.

The ratchet effect characterizes irrigated agriculture and municipal developments built during a period of several wet decades in the western U.S. There is intense political pressure to ensure that the expectation of water supply developed during recent wet decades continues to be met when the water yield returns to the longer-term normal or dry decades, as represented by data spanning two or more centuries. The politically expedient solution has been a pattern of transferring more water from wildland ecosystems to agriculture and municipal interests during normal or dry years. This decision is reinforced by the huge economic disparities that currently exist between different water uses. Water flowing in wildland systems is considered a free good, with reliable legal protection of base flow only in cases where endangered species rely on maintenance of aquatic habitat. In contrast, for example, 1.2 million liters of water (1 acre-foot) is currently valued for household use at US$1,311 in San Diego, California, USA, but is valued at US$17 when applied to irrigated croplands adjacent to that city. This pattern of water diversion has had a significant negative impact on maintenance of in-stream flow in many ecosystems of the world (Rijsberman 2006), particularly in regions dominated by arid and semi-arid rangelands. Consequently, the sustainability of wildlife, fisheries, and wetlands in rangeland ecosystems has reached a critical point in many regions of the world (Lemly et al. 2000). In-stream flow depletion is neither intended nor desired. Nonetheless, it is noteworthy that in-stream flow has continued to worsen over the last several decades despite widespread public and scientific awareness of growing negative impacts on rangeland ecosystems.

Perception of change

Many ecological processes occur at a slow, gradual rate that is difficult to perceive within a generational time-step. For example, interrill erosion on shallow sites may slowly reduce water-holding capacity. In such an instance, perplexed land users may experience an increasing frequency and severity of drought stress (perceived in the context of plant and livestock performance) compared with what previous generations experienced, even though the meteorological record indicates that there is no change in the timing or amount of annual precipitation. Encroachment of unpalatable shrubs may also occur over generations at a rate that is difficult to perceive. Loss of soil or encroachment of shrubs may result in lower forage production, necessitating the reduction of stocking rate across decades even though the year-to-year management seemed prudent (Thurow and Taylor 1999). Obviously, the long-term management was not appropriate for sustainable livestock grazing if unpalatable shrubs were encroaching and soil was being lost; management failed because the temporal scale of observation used by management was not sensitive enough to detect biophysical changes that manifest their impacts gradually over the course of generations.

Similarly, many socio-economic processes occur at a slow, gradual rate (e.g., the value of harvested commodities not keeping pace with the rate of inflation or life-style expectation, resulting in a reduced viability of enterprises that historically dominated the region). A gradual change in condition may also set the stage for rapid socio-economic change. For example, a struggling enterprise may rapidly collapse in the face of what otherwise would have been taken in stride as a short-term stress, such as a drought. Or gradual change in public sentiment may build until a political environment is created which suddenly gives way to rapid change in policy. For example, the gradual increase in public concern for the environment evolved in the U.S. over several decades before the political climate was ripe for enacting over several years a set of new laws [e.g., National Environment Policy Act (1969), Endangered Species Act (1973), National Forest Management Act (1976)] that radically altered management of U.S. rangelands.

Perception of risk

Risk tolerance of degradation of biophysical processes differs radically if the management planning horizon is years, decades, or centuries. For example, friction between ranchers and government officials is often driven by differences in risk tolerance. A rancher must balance short-term pragmatic financial obligations with long-term sustainability goals. Therefore, in the early stages of a drought, the rancher may be willing to accept more short-term risk of soil erosion or degradation of plant community than a government official charged with sustaining long-term biological production potential. The cumulative effects of ranchers accepting multiple short-term risks over the course of several generations, and sometimes guessing wrong, can lead to degradation that, at some point, may result in a self-perpetuating change and a transition to an alternative ecological state that is less useful from a human perspective.

Perception of monetary value

Monetary value is obviously highly subjective and is often influenced by a temporal context. For example, the time value of money (discount rate) is influenced by perceived risk, inflation, and benefits from alternative investment opportunities. Economic theory asserts that conservation will occur when the discount rate indicates that the future potential for benefits is deemed more valuable than the current demands. However, this is complicated by the fact that human behavior will likely be determined on an individual basis, reflecting a unique mix of risk tolerance and the perception of quantitative and qualitative benefits and costs. In extreme situations, the discount rate may be so high that anything other than meeting immediate needs is unacceptable. Thus, a starving pastoralist will rationally focus on doing whatever it takes to enable immediate survival for him and his family; future productivity considerations are of zero value if current needs are not met. In a less dire situation, the same choices can be made, such as the need to make the loan payments to avoid bankruptcy—future productivity of the ranch may seem of little consequence if there is imminent danger of losing ownership via foreclosure.

Partly because of the values implicit in the discounting detailed above, many economists remain skeptical of whether a focus on sustainability is a useful guide for policy (Nelson 1995). Just as some economists argue that running a deficit is a valid way to manage a country's operating budget, it follows that they reject sustainability due to the relatively small discount rate it implies. Furthermore, some economic analysis focuses on assessing the value of what is produced, rather than emphasizing the underlying conditions that make production possible. Ecosystem services are assessed in terms of what is produced for sale. Accordingly, the price of rangeland has been historically set by the value of livestock that could be produced, or, in more recent times in affluent countries, by the aesthetic value of the panoramic landscapes used as home sites. The rationale of valuing only what can be sold does not consider the very important non-marketed services these landscapes provide to society. The importance of non-marketed service considerations were effectively highlighted by the Chipko forest preservation movement of India whose slogan was What do forests bare? Soil, water, and clean air." Ecological economics is a growing field that attempts to factor in the ecosystem service values in a cost-benefit analysis conducted at a societal scale, including future valuation as well as today's market valuations. Ecological and conventional economists clash due to a mismatch in both temporal and spatial scales of their analysis.

Spatial scale issues

Overlap of management units with conflicting objectives

Many wild herbivore communities migrate, as do traditional pastoralists guiding their livestock. Such a strategy is adaptive for maintaining the flexibility necessary to cope with wide variability in forage production associated with the irregular spatial distribution of rainfall characteristic of many rangelands. Traditional political boundaries were established to secure resource access rights necessary to cope with the spatial variability of forage production and water distribution. As central government structures were created, other political considerations emerged such as regulation of security and commerce, or provision of health, education, and religion. These new political considerations imposed management units that had little or nothing to do with natural resource management, thereby undermining the traditional flexible movement patterns and associated management units that were developed with long-term ecosystem function at their core.

Artificial separation of dependent management units

Failure to recognize inherent biophysical connections within a landscape can trigger one-way chain reactions that create negative impacts in other portions of the landscape. For example, this commonly occurs when there is a disparity of management objectives between upland and lowland systems, such as heavy grazing and timber harvest in uplands increasing downstream susceptibility to flooding or siltation. In such a situation, the greatest benefits of conservation or reclamation of upland resources may be to the downstream interests. It is very difficult to fully assess the serial costs of upstream degradation to downstream interests or the serial benefits of upstream conservation or reclamation to the downstream interests (Thurow et al. 2000). Therefore, if the project area is delineated as an upland site, the off-site benefits are often not considered in a cost/benefit appraisal of the project. Consequently, the economic viability of a project may vary greatly depending on how the project area is defined. Assessing rangeland investments only in the context of rangeland products (a common practice) often does not consider, or grossly underestimates, the value of the project to off-site interests. It is often desirable to change the scope of analysis to include off-site interests in rangeland management investment decisions, in order to increase the potential for obtaining funds from off-site stakeholders. A reason for resistance to this practice from ranchers and pastoralists is that the priorities for rangeland management specified by people living away from the rangelands are often quite different from the priorities of people making their living from the rangelands.

Dependent planning units also operate disjointedly when natural resource management units are separated by cultural or political issues thereby limiting coordination. For example, a road that would aid livestock marketing and herd management in an area populated by clashing ethnic groups may be opposed by one or both groups because the road could also be perceived to be a security liability. Water development placement to optimize resource productivity may be opposed due to a variety of socio-political considerations, since removing this previously limiting factor may cause strife in areas that were once not considered worth contesting. Installation of communication infrastructure may be opposed by established marketing interests who would stand to lose profit if there were greater access by pastoralists to timely information (e.g., cellular phone systems are helping previously disenfranchised ethnic groups to access information by skipping over the step that once required politicians from different ethnic groups to license land-line installation).

Demand overwhelming production capacity of a management unit

The increase in the pastoral population, and the concomitant increase in livestock necessary to support these additional people, has undercut traditional management of communal lands (Brown 1971). This is done by individuals seeking to provide for their personal needs through private livestock ownership, while passing on the costs of their livestock grazing pressure to the communal unit (Hardin 1968). These demographic pressures, in tandem with the scale issues associated with political boundaries discussed above, have prompted attempts to reconfigure land use patterns toward systems based on privatization/sedentarization. Systems such as group ranches, grazing associations, or adjudication of previously communal land into privately owned parcels have generally not been of sufficient size to provide flexibility of movement necessary to cope with the irregular spatial distribution of rainfall and forage production, creating conditions that lead to long-term degradation (Ellis and Swift 1988).

A mismatch between production needs and plot size is not only limited to poor countries. In affluent countries, a disconnect between recreation demand, the quality of the recreation resource (biophysical limitation), and the quality of recreation experience (social considerations) is increasingly causing rangeland recreation amenities to deteriorate. Another trend in affluent countries is subdivision of ranches into private lots for housing. Many of these new home sites disrupt the ecology of the area in that they tend to be located on critical winter range or dry season pasture, thereby disrupting wildlife access to critical resources within the landscape which had been compatible with traditional livestock production. The homeowners also tend to be accompanied by pets (dogs and cats) creating subsidized predator densities far in excess of what could normally be supported. Confining pet herbivores such as horses or llamas to small pastures degrades the cover, creating runoff and water quality problems and promoting establishment of noxious weeds that provide seed sources to invade native rangelands.

Experience issues

Different experiences may cause people diverge in their interpretation of the same set of facts. For example, a waving field of yellow flowers under an open understory of shrubs was viewed as a desirable management goal when a picture of such a landscape was viewed by urban citizens, but was viewed with horror by ranchers who recognized the yellow flowers as belonging to a poisonous forb (*Hymenoxys odorata* DC) and who realized that the open understory of shrubs was created by extremely heavy browse pressure (S. Whisenant, personal communication). Perception and interpretation differences based on lack of knowledge can often be overcome with education.

Many terms used by managers and policy makers (e.g., drought, health, restoration) are, by their nature, ambiguous. In such cases the differences in emphasis and expectation embedded in the definition of the terms may be quite different for different stakeholders, fostering confusion and lagged responses as a result of muddled views. For example, expectation of inherently variable parameters such as precipitation are influenced by risk tolerance and by the length of time considered in the calculation of what is normal. Emphasis within the definition of drought is influenced by what is most important to the stakeholder. Therefore an agriculturalist may define drought in terms of when forage or grain production is less than expected, a hydrologist may define drought in terms of when water level in a reservoir is less than expected, a meteorologist may define drought in terms of amount of precipitation expected within a period of time, an economist may define drought in terms of when production declines begin to influence jobs or commerce. Given such diverse perspectives of emphasis, a short-duration intense storm may have enough precipitation to end a meteorological drought and may produce runoff to end a hydrologic drought, but may not help forage or grain production (agriculture drought). Conversely, a small amount of precipitation each day for a month may enable a large amount of forage or grain production, ending an agriculture drought but may do nothing to end a hydrological drought reflected by tracking water level in a reservoir. Confusion associated with the use of this term fosters inaction and leads to many policy makers portraying drought as temporary climatic aberration, when in reality it is a normal, albeit unpredictable, climatic phenomenon. This can enable drought being a scapegoat for faulty policies instead of being viewed as something that is a managerial responsibility. It also fosters moral hazard behavior in that lack of response to the risks of drought is routinely bailed out by emergency aid predicated on the assertion that a drought is unique and beyond the scope of proactive policy (Thurow and Taylor 1999).

Adaptive management of unintended consequences

Most managers and policy makers perceive that resource problems are not really environmental problems; they are human problems that we have created at many times and in many places, under a variety of political, social, and economic systems" (Ludwig et al. 1993). It is germane to emphasize that the political, social, and economic systems are not purposefully pursuing resource degradation. Rather, these consequences are unintended. Rangeland managers can learn from classical economic studies of human decision-making in markets to appreciate the pitfalls and possibilities of integrating optimization and sustainability goals of resource management. A central tenet of the Adam Smith's (preeminent economist of the 18th century) interpretation of human behavior was that an individual makes decisions intended to promote personal gain, but that in so doing also promotes unintended consequences. These unintended consequences may be manifest in various ways, either facilitating the social good of commerce or setting in motion self-sustaining biophysical feedback loops leading to desertification. However, human behavior is not solely driven by an attempt to achieve maximum personal gain in every transaction; there are also ethical preferences that modulate the rationale of individual choice (Harsanyi 1955). Rather than pure pursuit of self-interest (a rational fool), behavior is regularly altered by the commitment of individuals to non-monetary values. Exploration of this duality: the pursuit of immediate self interest and the commitment to broader ethical values, and how it alters behavior, was the contribution which won Amartya Sen a Nobel Prize in Economics. Smith's and Sen's perspectives offer hopeful insights to discussions of whether sustainability and optimization are useful concepts for rangeland management and policy formulation.

Tactical methods for dealing with the tension between optimizing self-interest and honoring the ethical values of sustainability goals in rangeland stewardship and policy often focus on adaptive approaches. Adaptive management is based on the notion that we often have insufficient information to anticipate ecosystem responses to human use, as well as inadequate information to understand how people make choices relative to their interactions with the ecosystem. Therefore, policy formulation and implementation is viewed as a process of learning to reconcile seemingly divergent views, with data from scientific experiments being pivotal. Scientists continually modify and augment today's research agenda according to what has been learned through past trials. This includes shifts in the scale and scope of scientific analysis. Policy formulation is viewed as a series of experiments from which lessons can be learned about how to ensure that human activity is compatible with the maintenance of the ecosystems services upon which humans ultimately depend. The ultimate role of science in this process is to provide information on what is biophysically possible and the environmental tradeoffs associated with balancing provision of multiple rangeland products.

Adaptive management has proven to be very difficult to achieve because the various temporal, spatial, and experience-based perspectives associated with framing a problem, such as those discussed in the previous sections of this paper, may work at cross-purposes and may mean different things to different stakeholders. It is therefore not surprising that it is extremely difficult to engage stakeholders with opposing priorities into an integrated decision making process. This is further complicated by many ingrained barriers in government institutions that are not amenable to providing the flexibility necessary for adaptive management to succeed (Johnson 1999). These common barriers to adaptive management illustrate that the limiting factor to resource management is not so much the need to assemble a mountainous accumulation of scientific facts, but rather is the difficulty of fostering insight into and reconciliation of social, economic, and ecological processes for the greater good (Lee 1999). These issues must be reconciled at the outset when attempting to form a collaborative structure for management and policy to build upon. This is easier said then done. Often the stakeholders attempting to implement an adaptive management process are doing well to coexist but cannot achieve true conflict resolution.

Where adaptive management cannot overcome vested interests working at cross-purposes against the ethical considerations associated with sustainability, there may be a temptation for scientists to become engaged in political discourse intended to help form policy that will compel intransigent self-interests to conform to behavior that will be compatible with the greater good. Scientists have understandably been reluctant to engage in overtly supporting political agendas because of the fear of losing a claim to objectivity, thereby encouraging opposing groups to question their credibility and disregard the scientific information they generate (Rykiel 1997). However, as scientists document the variety of environmental variables that are represented by the function shown in Figure 1, and as the implications of these trends are analyzed, there is a growing urgency among scientists who believe that the lag in responsiveness by governments is unacceptably slow or narrow. This is leading many scientists to realize that they need to become more effective at providing policy-oriented information to a broader audience. Some scientists are choosing to give up their cloak of scientific neutrality and assume an advocacy role to promote the enactment of better environmental policy.

Conclusions

The underlying philosophical goals of the rangeland management profession are sound, but the implementation of the joint goals of sustainability and optimization is becoming much more complex. The stakeholders making claims on rangeland products and shaping management priorities are increasingly diverse. The policy-relevant temporal and spatial scales are rapidly shifting and are highly context-specific. There is compelling evidence (Figure 1) that we are well underway to an unprecedented intensification of pressure on rangeland ecosystems. This pressure may threaten the sustainable provision of many rangeland products and services, an unintended consequence of current political, social, and economic systems. There is strong reason to believe that these human-derived systems influencing resource use patterns can be responsive to scientific input, but this is likely to occur only if the products rangeland scientists produce get much better at melding the ecological, economic, and social issues in ways that are directly responsive to addressing the barriers to integrated decision making. The motivation for challenging ourselves to improve at this task is the realization that our role as scientists will ultimately be determined by the new visions scientific insight can inspire among stakeholders and policymakers seeking to achieve sustainable management of rangeland resources.

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